

## FUNCTIONAL DISTURBANCES DURING HYPOKINESIA IN MAN

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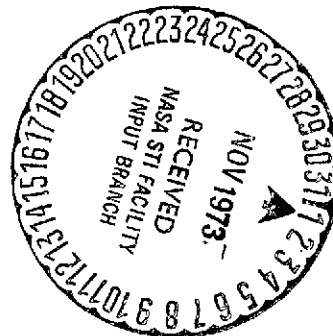
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| 16. Abstract<br><br>Two groups of three male volunteers each were confined to strict bed rest for 20 days. Group 2 performed exercises while in bed while group 1 did not; the members of the latter group showed a greater incidence of a neuroasthenic syndrome as well as more profound changes in circulatory parameters. Hence, physiological systems deteriorate with diffuse and this phenomenon must be taken into account when prescribing prolonged periods of bed rest. |                                                      |                                                          |                   |
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Strict bed rest can produce a number of disturbances in the organism, and /19\* is particularly likely to lead to thrombosis of the veins, hypostatic pneumonia, kidney-stone disease, etc. Numerous studies of healthy individuals who were observed in the course of bed rest, revealed a pronounced decline in the resistance of the organism to orthostatic effects and physical stresses, a decrease in the volume of circulating blood, muscular atrophy, negative nitrogen and minimal balance (A. L. Myasnikov et al.; L. I. Kakurin et al.; Guthbertson; Deitrick et al.; Taylor et al., 1945, 1949; Lamb et al., etc.). These authors attribute an important role in the etiology of these disturbances to hypokinesia.

During bed rest, the organism is subjected to the influence of two basic factors: limited muscular activity and a characteristic redistribution of the blood owing to changes in the hydrostatic pressure (Lawton, McCally, Graveline, Diringshofen, Vogt et al.).

For a differentiated study of the influence of these factors, we attempted to make up for the deficit of muscular activity during bed rest by means of physical exercises. For this purpose, we performed an experiment in which 6 healthy male volunteers spent 62 days in a horizontal position in bed. The basic problems to be studied were an evaluation of the influence of the combination of factors in the experiment on the human organism and a clarification of the role of hypokinesia proper.

The subjects were divided into 2 groups (3 men each). Motor activity of the subjects in the first group during their stay in bed was limited to a minimum and the subjects in the second group carried out a number of physical

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\*Numbers in the margin indicate pagination in the foreign text.

exercises daily (turning the pedals of a bicycle ergometer, touching rubber expanders, and static stressing of individual muscle groups (isometrics)). The intensity of the muscular stress during the first 15 to 20 days was 700-800 kcal per day, then 900-1,000 kcal per day and during the final 20 day period it reached 1,100 kcal per day (the average energy consumption in physical work was 1,000 kcal per day). If we take into account that an adult male at rest consumes an average of 2,400 kcal per day to maintain metabolism, the daily energy consumption of the subjects in this group coincided with the energy losses of individuals who perform rather heavy physical labor (metal workers, painters or catchers in metal rolling mills). The energy consumption of our subjects in their daily life was not great by any means; consequently, in this case hypokinesia could not have been the reason for the functional disturbances in the subjects of the second group.

Prior to the beginning and following the termination of the bed rest, we determined the force and tolerance of the muscles of the subjects and conducted tests on the bicycle ergometer to evaluate the resistance of the organism to calibrated and maximum stress; we determined the orthostatic tolerance and changes in the general center of gravity in the vertical position. At these times and during observation of bed rest we studied blood circulation and respiration, the tone of various muscle groups (as a function of their hardness), performed x-ray photometric studies of the mineral saturation of the bone tissue, recorded changes in body weight, size of extremities, physiological tremor and examined clinically the nervous system.

In the course of 62 days spent in bed subjects appeared sluggish and apathetic. During the very first weeks of bed rest they began to develop mild neurological symptoms that were indicative of the development of asthenic reactions. As the period of the experiment grew longer, these symptoms became more noticeable and a neurasthenic syndrome developed which was characterized by an increase in the tendinous and periosteal reflexes, a decrease in muscle tone (the impression was gained that the Oppenheim and Rossolimo reflexes had developed), more pronounced coordinational disturbances in the genua-calcaneal and finger-nose test, etc. More pronounced changes occurred in the subjects in the first group.

As far as the vegetative nervous system is concerned, there was a tendency toward tachycardia; the period of dermographism was increased, and the color changed from pale to bright pink; the difference in the pulse rate in the Ashner test increased. Variations in the general center of gravity following the stay by the subjects in bed showed an increase in both amplitude and frequency. The EEG showed a shift toward the low frequency side with a decline in the rate of development of electrocortical temporary links. These changes were more pronounced in the subjects of the first group.

The muscle tone, measured on the basis of their hardness, decreased gradually in the course of the experiment and particularly sharply in the subjects of the first group. The circumference of the shins at the end of the period of bed rest had decreased in the untrained subjects by 3 cm on the average and by 2 cm in those who had done the exercises. The strength characteristics of the individual muscle groups and the static tolerance showed a more pronounced decline in those subjects who had not performed the physical exercises (Table 1).

In all of the subjects in the first group, the optical density of the bone sample which was studied decreased by 10.5-20.7% (by 15% on the average) while in the subjects of the second group it decreased by 2-7% (4.7% on the average). /21

Oxygen consumption (and consequently basal metabolism) decreased in the subjects of the first group, beginning with the second 10 day period of bed rest and in the subjects of the second group beginning with the third such period. These characteristics fell to their minimum value after 30 to 40 days, after which they showed a relative stabilization at a new level. During the period of recovery following the experiment, oxygen consumption (basal metabolism) was close to the original level.

The frequency of cardiac contractions in the subject of the first group during bed rest increased gradually, the average hemodynamic pressure of the systolic and minute volume of the heart and the pulse pressure increased while the period of expulsion, mechanical and electrical systole shortened. In the second group of subjects the pulse rate (after a slight initial rise) varied around a single level, the pulse pressure and systolic volume did not change,

and the increase in the minute volume was less pronounced than in the subjects of the first group.

TABLE 1. CHANGES IN STANDING FORCE. (IN kg).

| Group | Subject | Force             |                | Change (in %) |
|-------|---------|-------------------|----------------|---------------|
|       |         | Prior to bed rest | After bed rest |               |
| 1-a   | F       | 207               | 157            | -24,2         |
|       | R       | 220               | 190            | -13,7         |
|       | S       | 205               | 168            | -18,1         |
|       | average | 210,6             | 171,6          | -18,6         |
| 2-a   | Z       | 240               | 211            | -12,1         |
|       | G       | 165               | 165            | 0             |
|       | M       | 220               | 200            | -9,1          |
|       | average | 208,3             | 192            | -7,9          |

Commas indicate decimal points.

As the result of a prolonged bed rest, the subjects in the first group showed a marked decrease in orthostatic resistance, which took the form of syncopal states, observed in one subject on the 60th day of bed rest, and in another during the first days of the recovery period. After the subject had assumed a vertical posture his pulse rate was found to have increased significantly, there was an increase in the minimum and average hemodynamic pressure, a decrease in the amplitude of the pulse pressure as well as systolic and minute volume of circulation of the blood.

Subjects who had performed physical exercises in bed withstood the orthostatic effects much better: in the vertical position they showed normal values for pulse rate increase and the minute volume of blood even increased (Table 2).

In a test with a metered physical stress (500 kilogram-meters per minute for 8 minutes) on a bicycle ergometer, performed following bed rest, the subjects in the first group showed a marked deterioration of the pulse reaction; there was an increase in the pulse rate during the work and it was particularly pronounced following termination in the recovery period; during the recovery period, its increase was 80% on the average for each group. In the subjects who had done exercises the pulse rate during work and during the recovery period was close to the original level, although during rest it increased to approximately the same degree as in the subjects who had not done exercise (see the figure).

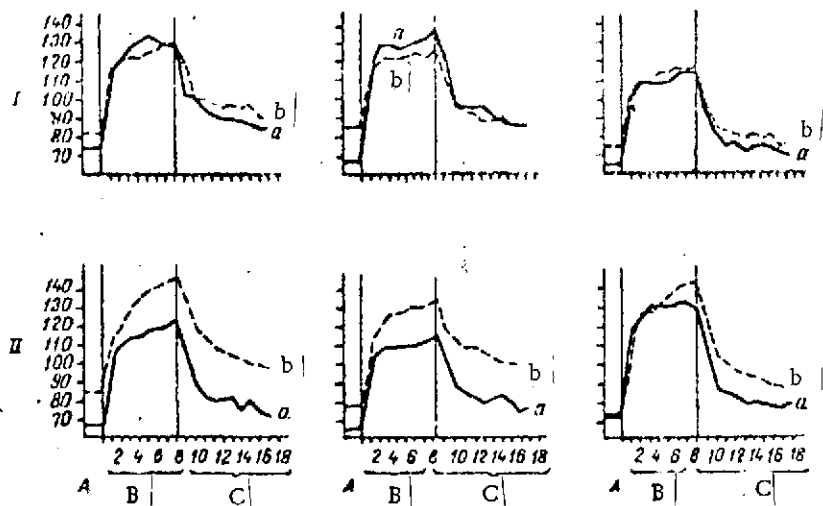
TABLE 2. CHANGE IN HEMODYNAMIC INDEX DURING THE ORTHOSTATIC TEST (AVERAGES)

| Index                           | Group of subjects | Before bed rest | 60th day of bed rest |
|---------------------------------|-------------------|-----------------|----------------------|
| Increase in pulse rate (in min) | 2                 | 25              | 21                   |
|                                 | 1                 | 23              | 56                   |
| Pulse pressure (in mm)          | 2                 | 27              | 23                   |
|                                 | 1                 | 34              | 15                   |
| Stroke volume (in mm)           | 2                 | 37              | 39                   |
|                                 | 1                 | 44              | 18                   |
| Minute volume (in liters)       | 2                 | 2,8             | 3,8                  |
|                                 | 1                 | 3,3             | 2,5                  |

Commas indicate decimal points.

The test with maximum physical stress revealed a pronounced difference in the working capacity of the subjects. While on the second day following the end of bed rest the total amount of work performed in the test by the subjects in group 2 showed practically no change (increased by 4%) in comparison with the controls, the working capacity of those who had not been exercising had decreased by 43% on the average

(26-54%). For a given amount of work, the pulse rate in the subjects of the second group was equal to the original level or below it, while in those who had not exercised it was always much greater (Table 3).



Pulse Frequency During Performance of Metered Physical Work. I, Subjects in group 2; II, subjects in group 1; a, prior to bed rest; b, after bed rest; A, rest; B, stress; C, recovery. Ordinate, number of strokes per minute; abscissa, time (in minutes).

TABLE 3. PERFORMANCE OF WORK AND PULSE RATE  
(IN MINUTES) AT A LOAD OF 1,200 kgm/min BEFORE AND AFTER  
BED REST.

| Subject | Performance of work (in min) |                      |                  | Pulse rate            |                      |                  |
|---------|------------------------------|----------------------|------------------|-----------------------|----------------------|------------------|
|         | before<br>bed<br>rest        | after<br>bed<br>rest | Change<br>(in %) | before<br>bed<br>rest | after<br>bed<br>rest | Change<br>(in %) |
| group 1 |                              |                      |                  |                       |                      |                  |
| F       | 5 800                        | 3 000                | -48,3            | 156                   | 178                  | +14,1            |
| R       | 6 600                        | 3 000                | -54,6            | 158                   | 171                  | +8,2             |
| S       | 5 800                        | 4 300                | -25,9            | 152                   | 166                  | +9,2             |
| average | 6 067                        | 3 433                | -43,4            | 155                   | 172                  | +11,0            |
| group 2 |                              |                      |                  |                       |                      |                  |
| Z       | 5 400                        | 5 800                | +7,4             | 154                   | 154                  | 0                |
| G       | 5 090                        | 5 800                | +13,9            | 165                   | 166                  | +0,6             |
| M       | 5 400                        | 4 900                | -8,7             | 155                   | 146                  | -6,8             |
| average | 5 297                        | 5 510                | +4,0             | 158                   | 155                  | -1,9             |

Commas indicate decimal points.

The deterioration of the functional state of the human organism under the influence of hypokinesia caused by bed rest has been repeatedly mentioned by many researchers. However, we are evidently the first to have completely eliminated the deficit of muscle activity during prolonged bed rest. In any case, we were unable to find anywhere in the literature studies where the energy losses involved in physical work during bed rest were in excess of 200 to 300 kcal per day, while in our experiment they were about 1,000 kcal per day on the average.

/23

The data which we obtained concerning the various functional disturbances that arose in the subjects in the course of a 62 day experiment may be grouped conditionally as follows:

1. Problems which could be eliminated by means of physical exercise, making up (through energy losses) the deficit of muscle activity, i.e., problems directly caused by hypokinesia. This includes in particular the resistance of the organism to metered and maximum stress and muscle strength.

2. A decrease in muscle tone, changes in calcium metabolism and x-ray density of bone tissue, physiological tremor and regulation of human posture, resistance to orthostatic effects, development of a neuroasthenic syndrome, etc.

Physical exercise proved to have only a limited positive effect on these phenomena, in other words, these changes continued to occur but they were much less pronounced than in the subjects in group 1.

The reasons for the deterioration of the condition of the subjects who had done exercise may be very diverse. Thus, the decrease in basal metabolism during bed rest may be explained as a change in the neuro-humoral interrelationships caused by adaptation of the organism to changing conditions, as well as an increase in the degree of training of the subjects under the influence of daily exercise (B. S. Katkovskiy).

The insignificant decrease in the x-ray density of the tissue of the shinbone in the subjects in group 2 may be explained by having insufficient stress on the foot, since the complex of physical exercises that was used was aimed only at compensation of the energy losses of the organism and not at simulation of the stress undergone by the support-motor apparatus during walking and standing. The development of a neuroasthenic syndrome apparently had no direct relationship to hypokinesia. Most likely the reason for it can be found in the entire complex of experimental factors (including the relative isolation, low level of external stimulation, forced stay in a horizontal position, etc.). The greater degree of manifestation of the neuroasthenic syndrome in the subjects of group 1 evidently had to do with the lack of physical training.

In this experiment, the physical training turned out to have a noticeable favorable influence on the tolerance to orthostatic effects: the increase in the frequency of cardiac contractions in the subject of group 2 in the vertical position prior to the bed rest was 25 beats per minute, and 21 on the 60th day, while on the first day of the recovery period it was 27 beats per minute, while in the untrained volunteers these values were 21, 56 and 51 respectively. In addition, when the volunteers who had exercised assumed a vertical position, they did not show any syncopal states and the minute volume of the heart even increased slightly in comparison with the original value, while in those who did not exercise there were 2 cases of syncope and the systolic and minute volume of the heart decreases (see Table 2). The minimal, pulse and final

systolic pressure in the subjects who exercised, upon a transition to a vertical position, changed more significantly than prior to their bed rest but less than in those who had not undergone physical training. The beginning of normalization of these parameters in the subjects in group 2 could be seen by the second day of the recovery period while in the subjects of group 1 it only appeared after 10 days.

3. The disturbances that were unaffected by physical training include changes in the water-electrolyte balance of the organism (Ye. N. Biryukov et al.) as well as changes in the functional state of the auditory analyzer, as was recently reported by I. Ya. Yakovleva and E. I. Matsnev. Probably the reasons for these functional disturbances is not hypokinesia but changes in circulation caused by the decrease in hydrostatic pressure or other factors whose cause /24 remains to be studied.

The data which we obtained confirmed once again the general biological law of a decrease in the capacity of any physiological system during diffuse and force the clinical position to take into account those disturbances which arise in the course of prolonged bed rest during treatment.

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